Creating Web-based Solar Maps

Mapping Applications based on LiDAR Data

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Introduction

Portugal, as a member of the European Union (EU), has to implement the Energy Performance of Buildings Directive which requires all EU countries to enhance their building regulations and to introduce energy certification schemes for buildings. Energy Performance Building Regulation is already implemented in Portugal since April 2006, and requires, among others, a minimum contribution from solar systems based on the type and size of the building. This new awareness, associated with the fact that Portugal is one of the European countries with the highest levels of annual solar radiation [1], contributes to a growing interest in the quantification of energy-based indicators at the city and building's scale, in order to assess photovoltaic (PV) conversion and thermal solar potential.
The aim of this work is to develop a methodology for identifying the solar energy available at the roof-tops, and presenting it in a web-based environment. For the identification step, the use of Light Detection and Ranging (LiDAR) data and Geographic Information System (GIS) for modelling the solar energy at the urban scale is proposed. Then, the results are made available in a web-based urban solar map, indicating the buildings suitability for installing solar systems, and the city's capacity for solar power.

Study Area and Dataset

The experiment is applied in an area located in heart of the city of Lisbon – Avenidas Novas – that occupies 625 ha (2.5 X 2.5 km). The street network is dense and most of the area is built-up, including three major avenues (Av. República, Av. Fontes Pereira de Melo and Av. Liberdade), green areas (Parque Eduardo VII, Fundação Gulbenkian), multi-family housing, commercial areas and two university campus (Figure).

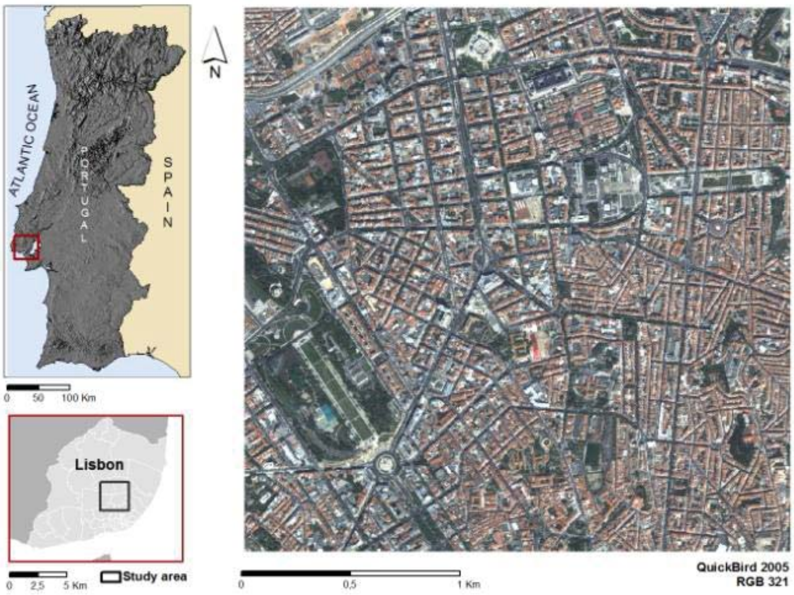

Figure 1. Study area for Solar Potential Analysis in Lisbon

The spatial database used in this case study included planimetric and altimetric data. The planimetric information was the Building's layer of the 1:1000 scale Municipal Cartography from 1998. The altimetric data was derived from a LiDAR point cloud. From a flight with a LiDAR camera performed in 2006, a surface image was produced based on the 2^{nd} return, with 1 m resolution. This image represents the DSM of the area (Figure 2).
All files were geometrically corrected to attribute a common coordinate system (PT-TM06/ETRS89).

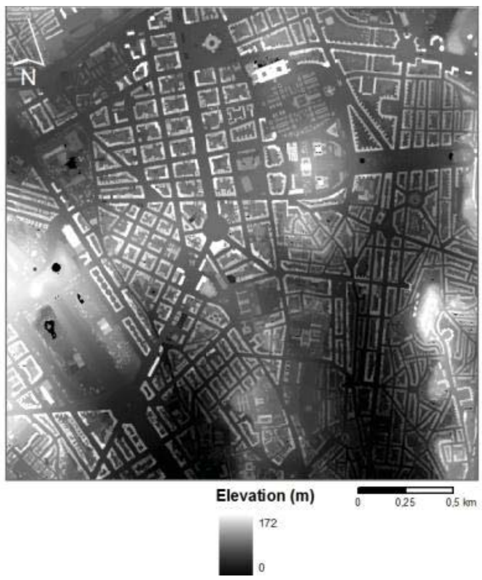

Figure 2. Digital Surface Model of the study area

Methodology

Identifying the solar income at the buildings' level requires modelling the solar radiation incident in each location. Two inputs are required: a DSM and the

buildings' footprints. With these data, modelling the solar radiation can be done in a GIS environment.
The incident solar radiation can be measured by ground-based meteorological stations or meteorological satellites, or be estimated through models. There are several solar models available in the literature. They vary in the detail of the input parameters and, consequently, in the output map. Solar Analyst and Photovoltaic Geographical Information System (PVGIS) are two examples of solar radiation models.
The Solar Analyst module in ArcGIS can be used to calculate Watt-Hours/meter^2 at the surface and at the local scale [2]. Inputs to this process are a digital elevation model, the latitude of the scene centre, the sky size, and the date and time one wishes to accumulate insolation and radiation parameters such as Transmittivity and Diffuse proportion. Therefore, the model accounts for atmospheric effects, as well as site latitude and elevation, steepness (slope) and compass direction (aspect), daily and seasonal shifts of the Sun angle, and effects of shadows cast by surrounding topography.
The PVGIS, developed by the Joint Research Centre (JRC), allows users to estimate solar energy performance at any given location. PVGIS built a GIS-based methodology for computation of solar irradiance/irradiation at a given surface inclination for any geographical region and for any time moment or interval. For each time step during the day the computation accounts for sky obstruction (shadowing) by local terrain features (hills or mountains), calculated from the digital elevation model. This model is a grid with 1 km resolution, derived from the U.S. Geological survey (USGS) Shuttle Radar Topography Mission (SRTM) data.
Both models are used in this work for calculating solar irradiance.
A two-step methodology is proposed: calculating the solar energy for the whole surface, and then assessing it at the roof-tops.

Solar Energy at the Surface

The first step is obtaining the solar energy at the surface level (SolarSurf). This is accomplished with the Area Solar Radiation tool, available in ArcGIS, that derives the total amount of incoming solar radiation (direct + diffuse) calculated for each location of the input raster surface. The model accounts for site latitude and elevation, surface orientation, shadows cast by surrounding topography, daily and seasonal shifts in solar angle, and atmospheric attenuation [2]. Therefore, by inputting a user specified model (a Digital Terrain Model or, more desirable, a DSM), the tool, after parameterization, produces a solar map that accounts for local topographic influences on solar radiation over the study area. This aspect is particularly important in urban areas, where shadowing effects are very common.
For characterizing the elevation of the study area, the local DSM was used. Regarding the insolation parameterization, the annual values calculated by the Area Solar Radiation tool differ from the ones produced by PVGIS, that has an accuracy estimate associated [3]. Therefore, monthly parameters (Diffusion and Transmittivity) were estimated based on PVGIS data available at Lisbon's latitude [4].

Figure 3 presents the SolarSurf map produced based on the local DSM and radiation parameters.

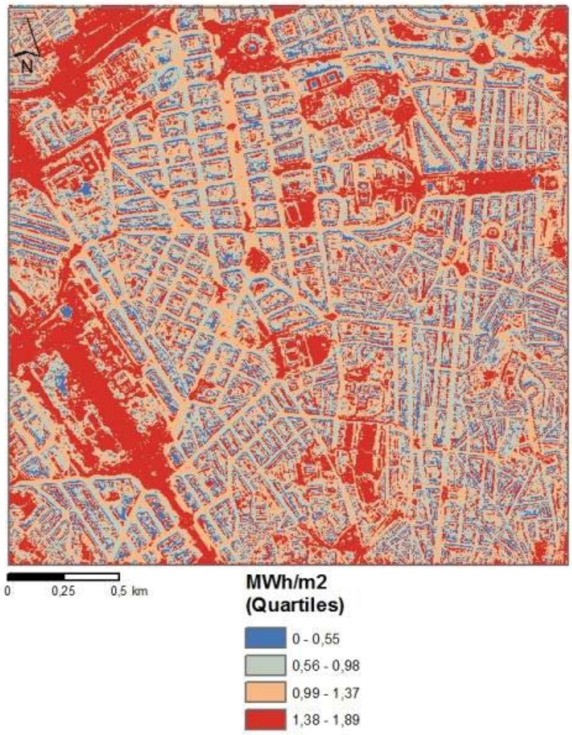

Figure 3. Mean annual solar radiation available at the surface (SolarSurf)

Solar Energy on the Roof-tops

The next step in analyzing is obtaining detailed information on the amount of radiation that reaches the roof-tops. So, after solar mapping at the surface, the solar radiation at the roof-top can be obtained using the building footprints.

The SolarSurf obtained in the previous step, was then combined with the Buildings' layer. This operation produced the map with annual solar radiation available at each pixel of the roof. The number of buildings evaluated in this area is 12344.

Averaging the energy of all pixels of each roof, created the map with the mean annual solar radiation available at each roof-top (SolarRoof).

Figure shows the SolarRoof for the entire study area, and three close-ups, that detail the FCSH site (area 1), a high school (area 2) and two building blocks in downtown (area 3).

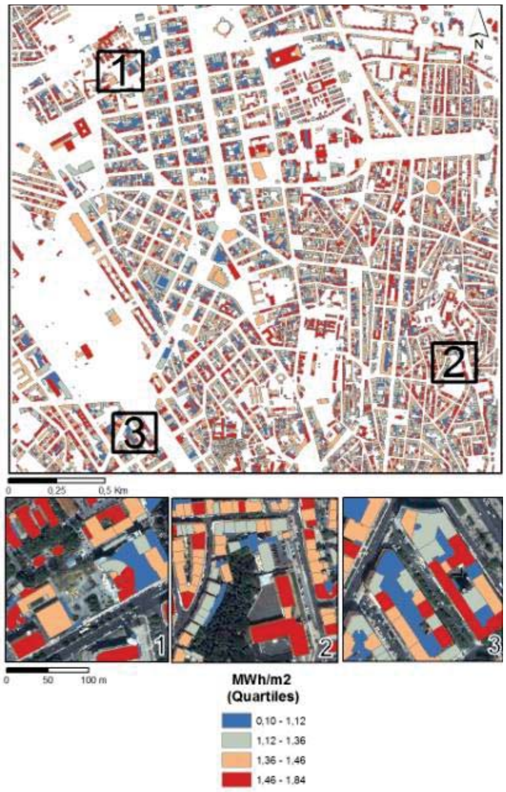

Figure 4. Mean annual solar radiation available at the roof-tops (SolarRoof)

Web-based Urban Solar Map

In the final methodological step, the mean annual solar radiation map was exported for a web-based format. The Google Earth KMZ file provides all users with access to the SolarRoof map through Google Earth, for 3-dimensional visualization (Figure 5).

Figure 5. Web-based Urban Solar Map

Concluding Remarks

To set up solar technologies, detailed solar suitability information on every building in a community should be available for urban planners. An efficient tool to address community energy objectives are interactive web-based urban solar maps. Such maps take advantage of GIS and visualization technologies, offering a solid knowledge base on available solar resources and best practices in solar energy technologies, providing a unique guide to the solar industry and the general public. Furthermore, solar maps also offer a comprehensive planning tool to the municipalities, allowing evaluating energy reduction opportunities for new and already existing buildings, plan the future energy consumption and supply, or monitor the compliance with energy and greenhouse gas goals.

The availability of information in a widespread visualization software like Google Earth, offers enormous potential, although it does not come without risks. Through superimposing satellite imagery and different layers, new realities are being built. These create new cognitive maps which alter the way individuals view the surface where they interact. The potential benefits of such applications justify they development. Yet, quality control measures should be developed and implemented.

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